

Search for the  $\Delta^{++}$  from  $pp \rightarrow n (p\pi^+)$  process

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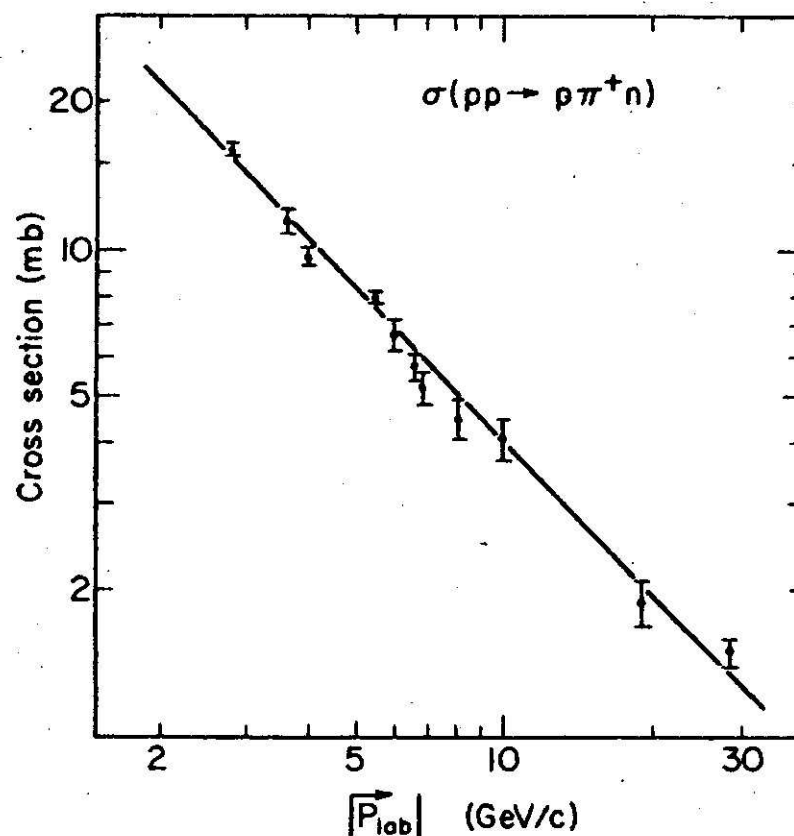
University of Michigan

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## Search for the $\Delta^{++}$ from $p + p \rightarrow n + (p + \pi^+)$ process

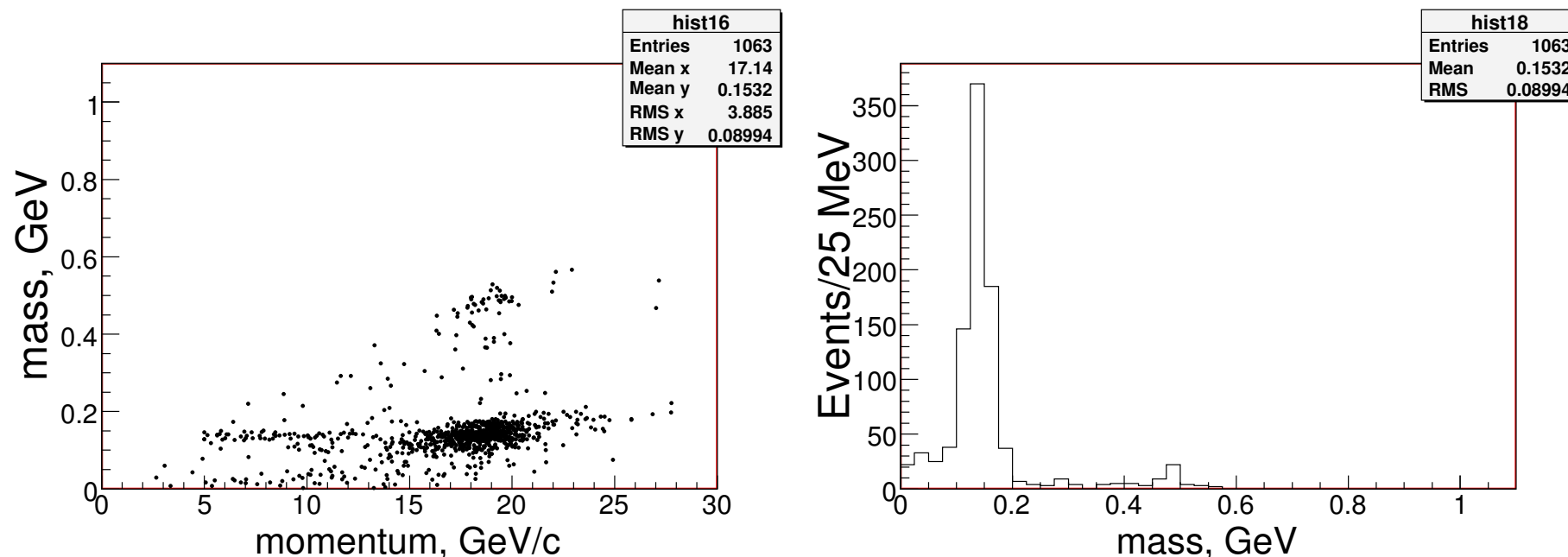
- Momentum - 20, 35 and 58 GeV/c
- Target: LH2, Carbon 2%, Bismuth and Uranium
- Trigger: proton beam and proton interactions
- Kinematic cuts:
  - $p_p > 2.5 \cdot p_\pi$ ,
  - $(p_p + p_\pi) > 0.8 \cdot p_{beam}$
- Event/track selection cuts:
  - select clean events,  $nTrks < 10$
  - select two track vertices
  - the vertex should be within the target sizes
  - require the good quality tracks in the vertex: reasonable nTPC hits, timing and  $p_{tot} > 0.2$  GeV/c
  - reject track if RICH identified it as a e/K track:  $0 < mass < 0.075$  GeV or  $0.2 < mass < 0.7$  GeV
  - apply a pion hypothesis for the track if RICH identified it as a pion,  $p_{tot} > 5$  GeV/c

## cross section



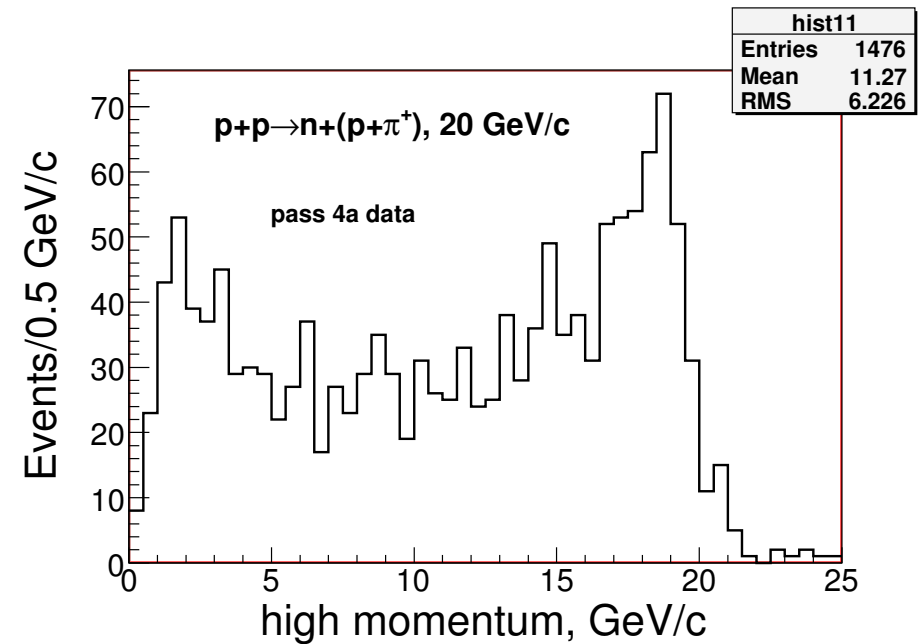
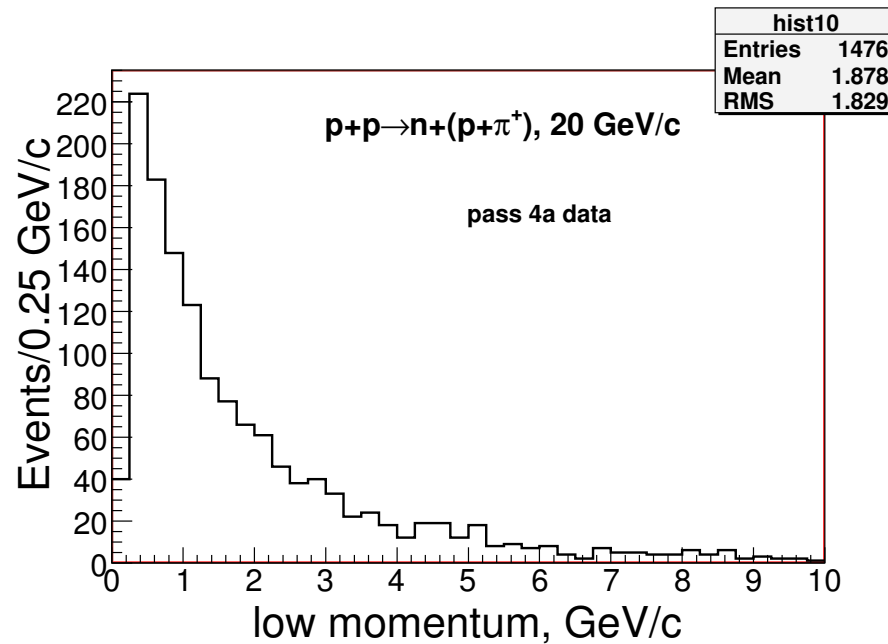
Experimental cross section for reaction  $pp \rightarrow np\pi^+$  as a function of beam momentum. The solid line is a fit result:  $\sigma = 45.9|P_{lab}|^{-1.06}$  mb. E.Colton et al, Phys.Rev.D v.7 (1978) 3267

# RICH info



The RICH detector info associated with the selected tracks: the mass vs momentum scatter plot (on left) and mass distribution on right plot. Plots indicates that the RICH detector identified the tracks: as  $e^{\pm}$  if  $\text{mass} < 0.075$  GeV, as a pion if  $0.075 < \text{mass} < 0.2$  GeV and as a kaon if  $0.2 < \text{mass} < 0.7$  GeV. The proton with  $p_{tot} < 20$  GeV/c is below of the RICH threshold.

## track momentum

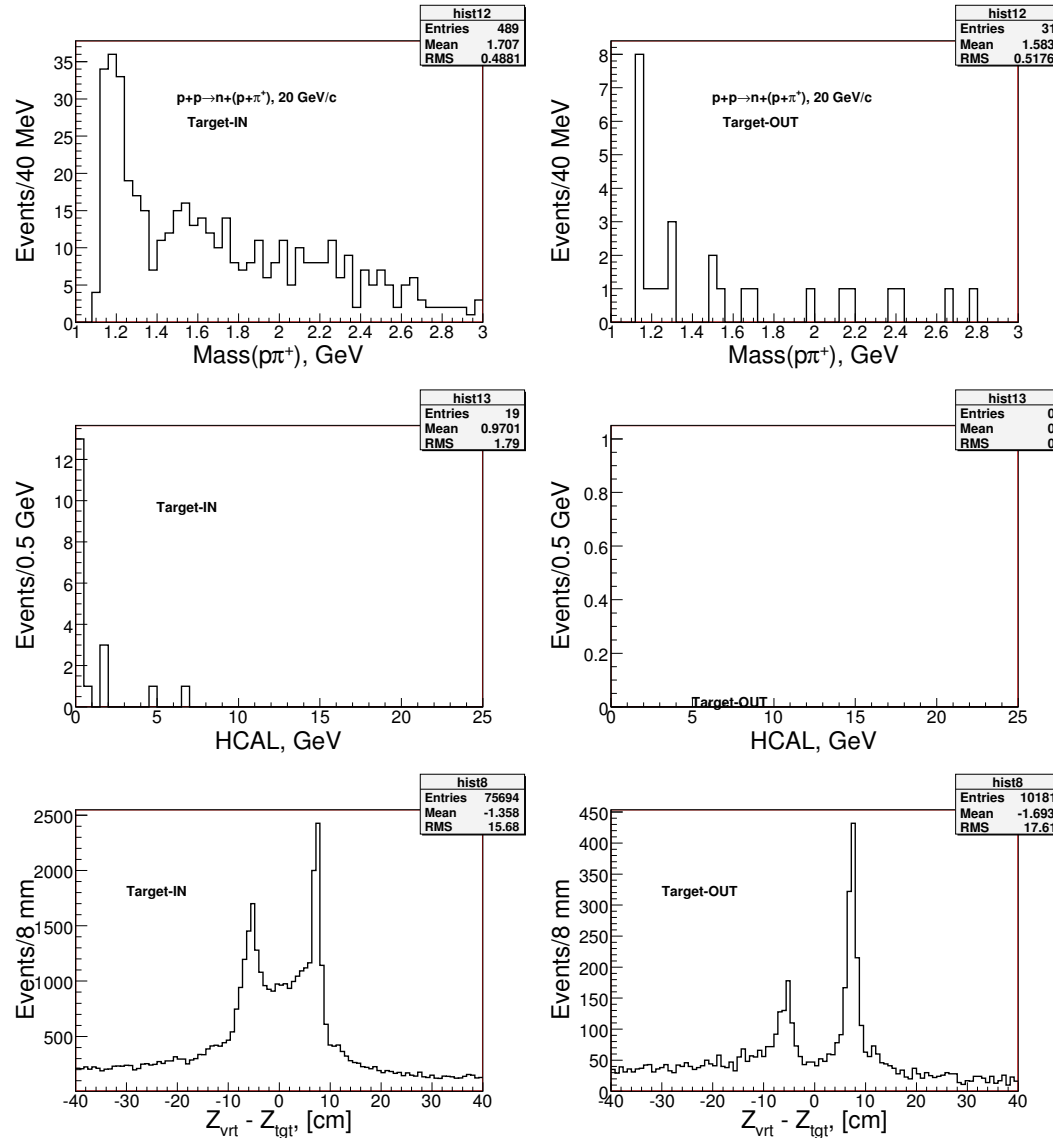


The momentum distributions of pair tracks passed all selection cuts: left plot - the low momentum track, right plot - high momentum track. Vertices with the pair of positively charged tracks were selected.

Based on kinematics the low momentum track is a pion, high momentum - a proton.

# 20 GeV/c protons on LH2 target data

Left plots - target-IN, right plots - empty Cryo target.



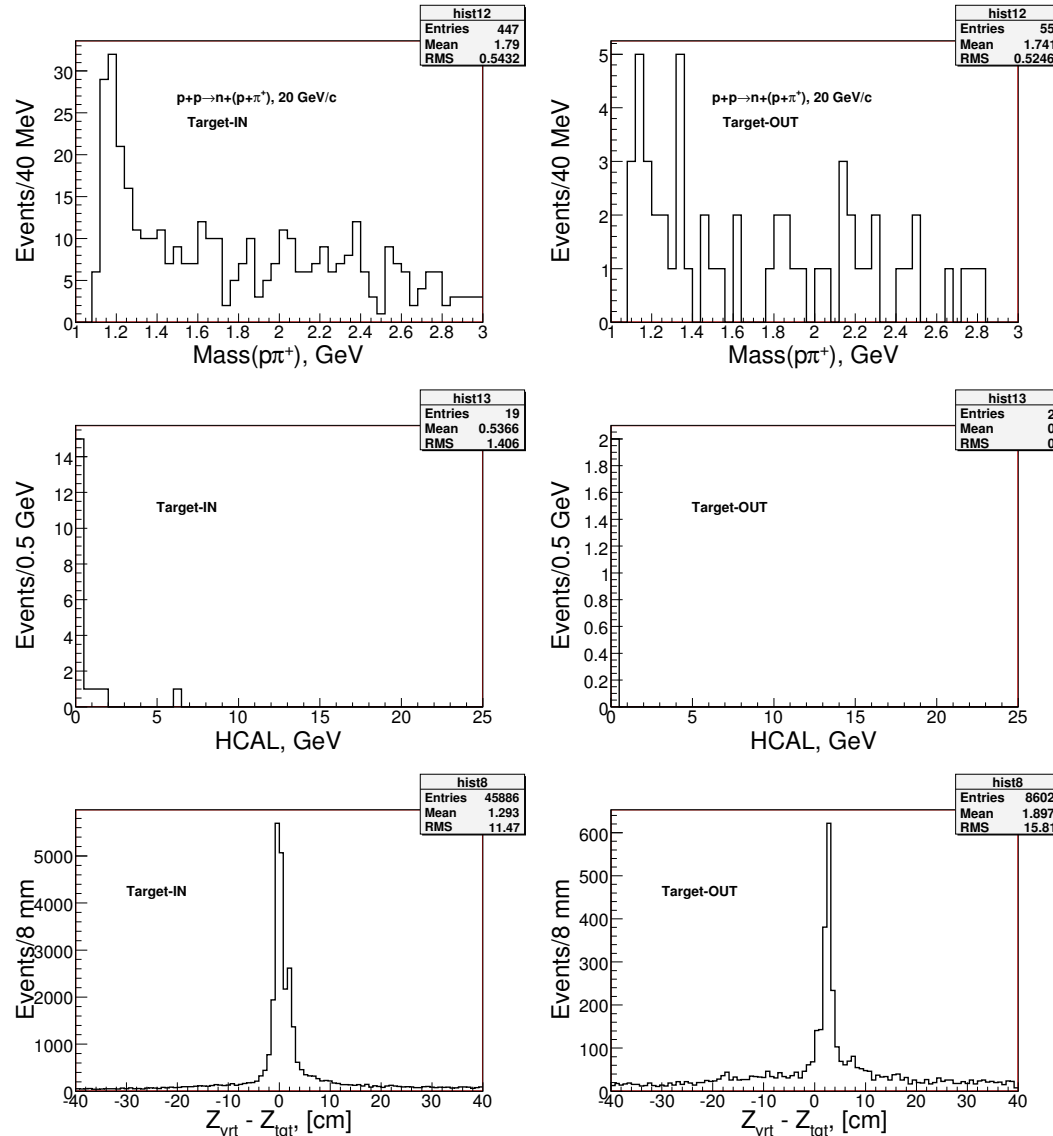
**Top** - the invariant mass distributions of pair positively charged tracks from the two track vertices.

**Middle** - deposited energy into HCAL with additional selection cuts: a) the mass of  $p\pi$  system should be within 1.1 - 1.4 GeV region and b) no any charged tracks pointing to the calorimeter area.

**Bottom** - the vertex Z position distributions of the multi-track vertices.

# 20 GeV/c protons on Carbon target data

Left plots - target-IN, right plots - target-OUT.



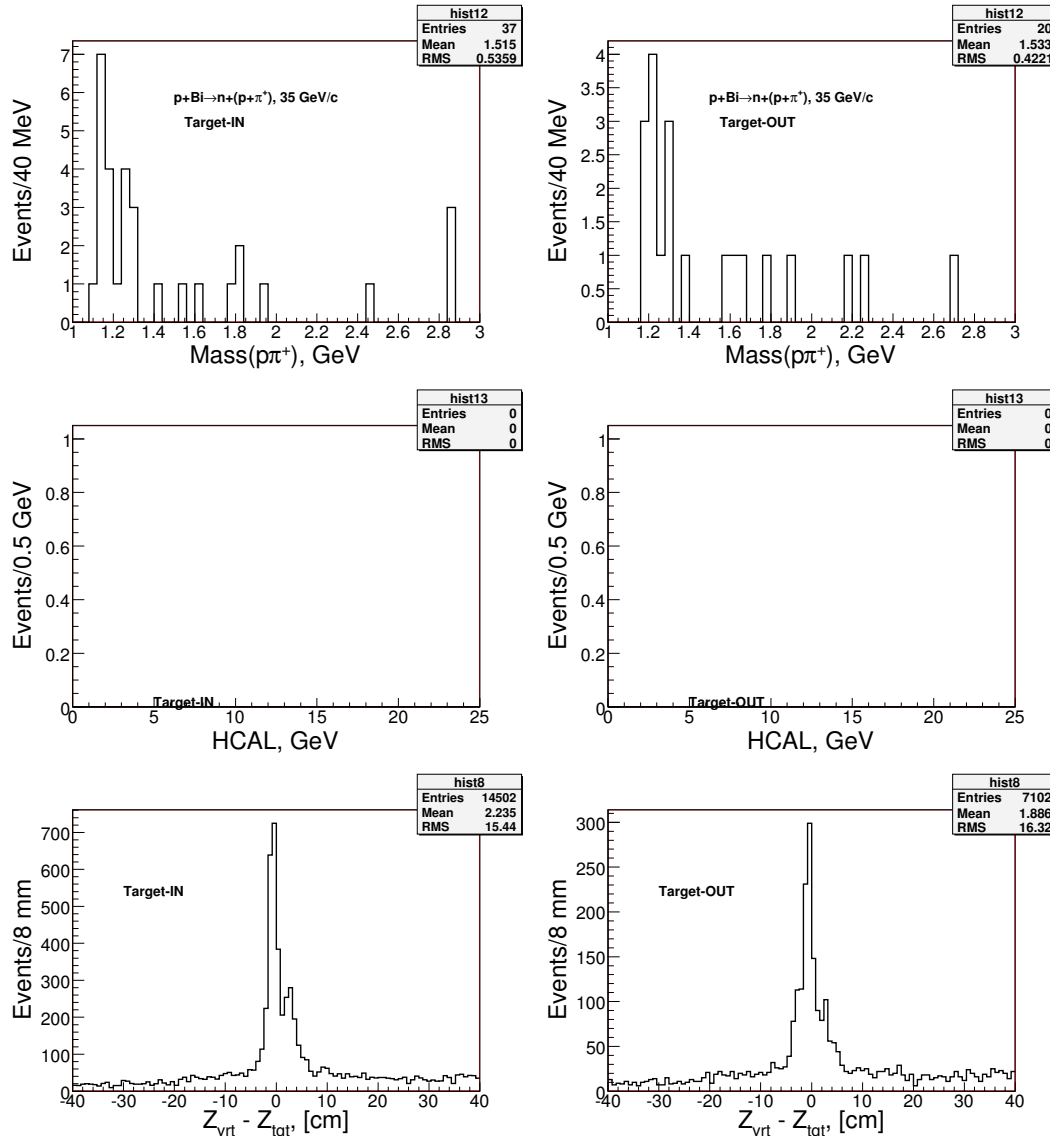
**Top** - the invariant mass distributions of pair positively charged tracks from the two track vertices.

**Middle** - deposited energy into HCAL with additional selection cuts: a) the mass of  $p\pi$  system should be within 1.1 - 1.4 GeV region and b) no any charged tracks pointing to the calorimeter area.

**Bottom** - the vertex Z position distributions of the multi-track vertices.

# 35 GeV/c protons on Bismuth target data

Left plots - target-IN, right plots - target-OUT.



**Top** - the invariant mass distributions of pair positively charged tracks from the two track vertices.

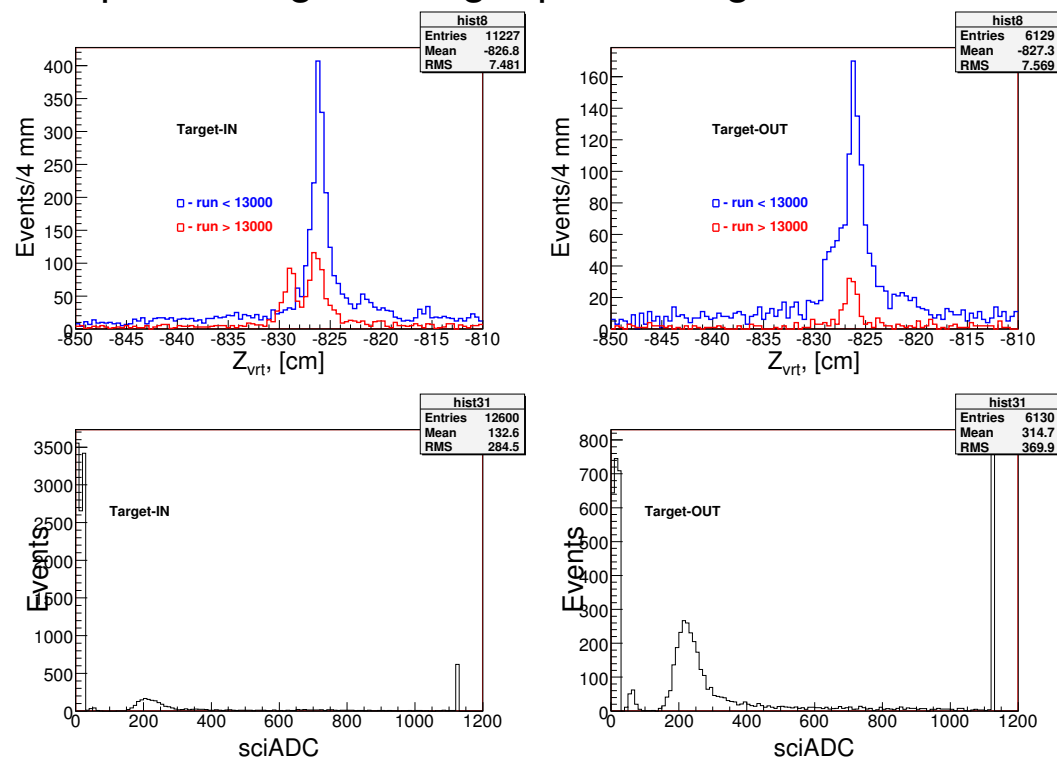
**Middle** - deposited energy into HCAL with additional selection cuts: a) the mass of  $p\pi$  system should be within 1.1 - 1.4 GeV region and b) no any charged tracks pointing to the calorimeter area.

**Bottom** - the vertex Z position distributions of the multi-track vertices. Target-OUT peak position looks strange. See details on next page.



## more about Bismuth target data (35 GeV/c)

Left plots - target-IN, right plots - target-OUT.



More trigger counter plots are several pages below

**Top** - the vertex Z position distributions of the multi-track vertices. Red plots - run < 13000, blue - run > 13000. Peak at z = -827 cm represents interactions with the trigger counter. Peak on red target-IN plot at z = -829 cm represents interactions with Bismuth target. Why we not see it on blue plot? Because the trigger counter do not work properly at this time.

Another note - Z target position at DB:

Run12721 tgtPos=(-0.109,-0.173, -825.4?)

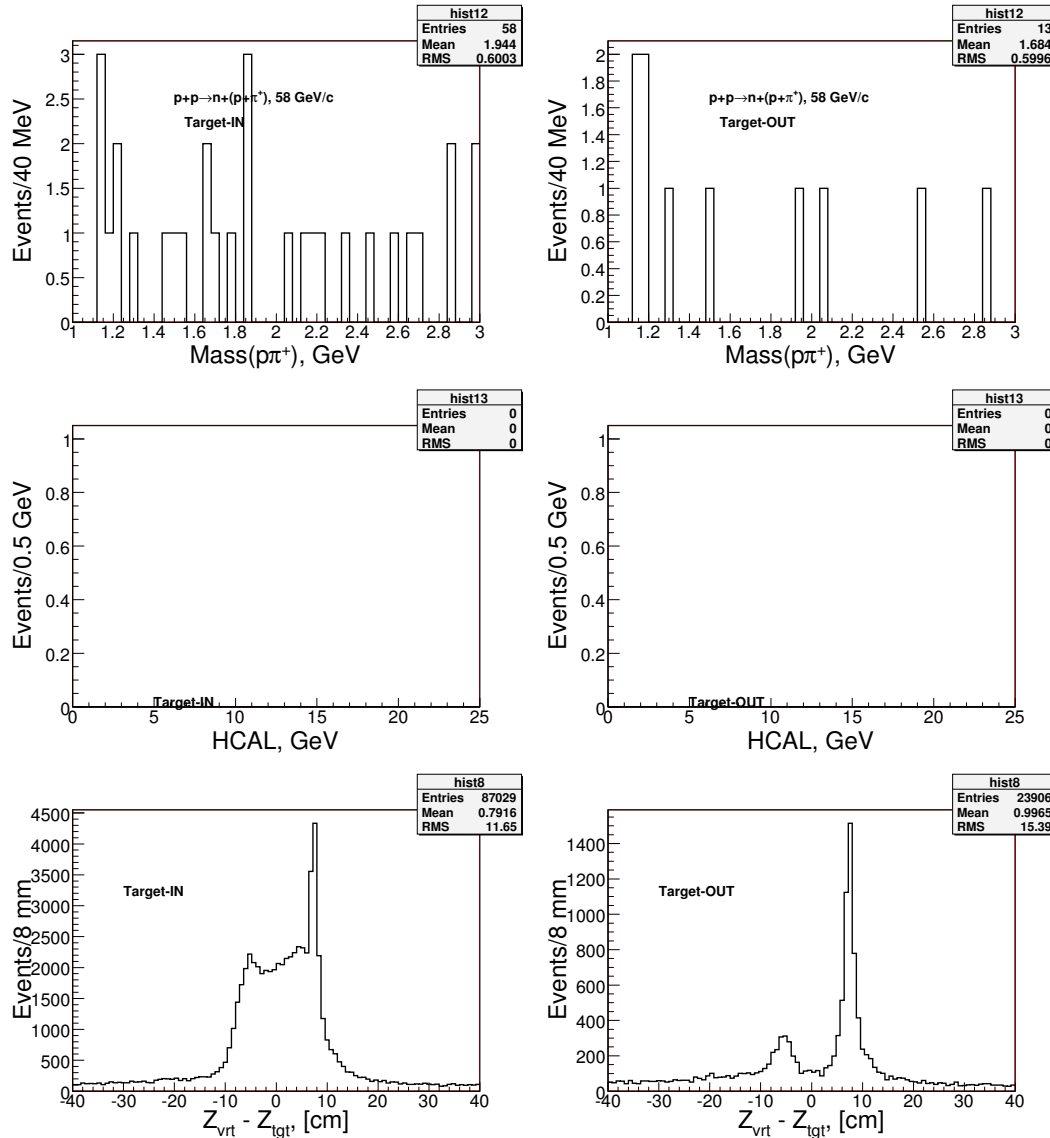
Run14076 tgtPos=(-0.109,-0.173,-829)

DB suggests that Z for empty target is -825.4 cm which is downstream of the trigger counter. It can not be true.

**Bottom** - the trigger counter ADC distributions. Plots illustrates that the target-IN data were taken when the counter has readings below of the pedestal

# 58 GeV/c protons on LH2 target data

Left plots - target-IN, right plots - empty Cryo target.



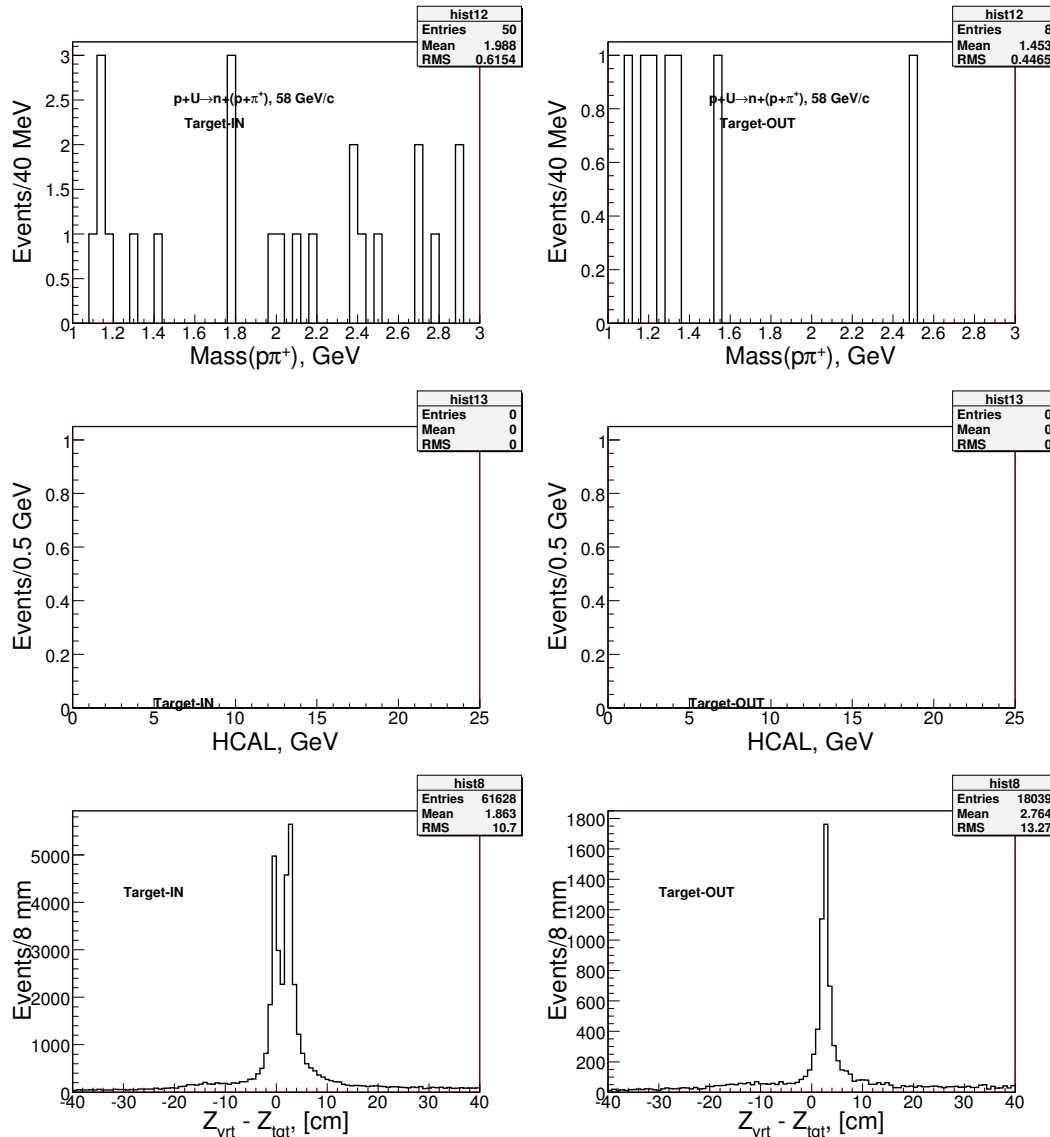
**Top** - the invariant mass distributions of pair positively charged tracks from the two track vertices.

**Middle** - deposited energy into HCAL with additional selection cuts: a) the mass of  $p\pi$  system should be within 1.1 - 1.4 GeV region and b) no any charged tracks pointing to the calorimeter area.

**Bottom** - the vertex Z position distributions of the multi-track vertices.

# 59 GeV/c protons on Uranium target data

Left plots - target-IN, right plots - target-OUT.

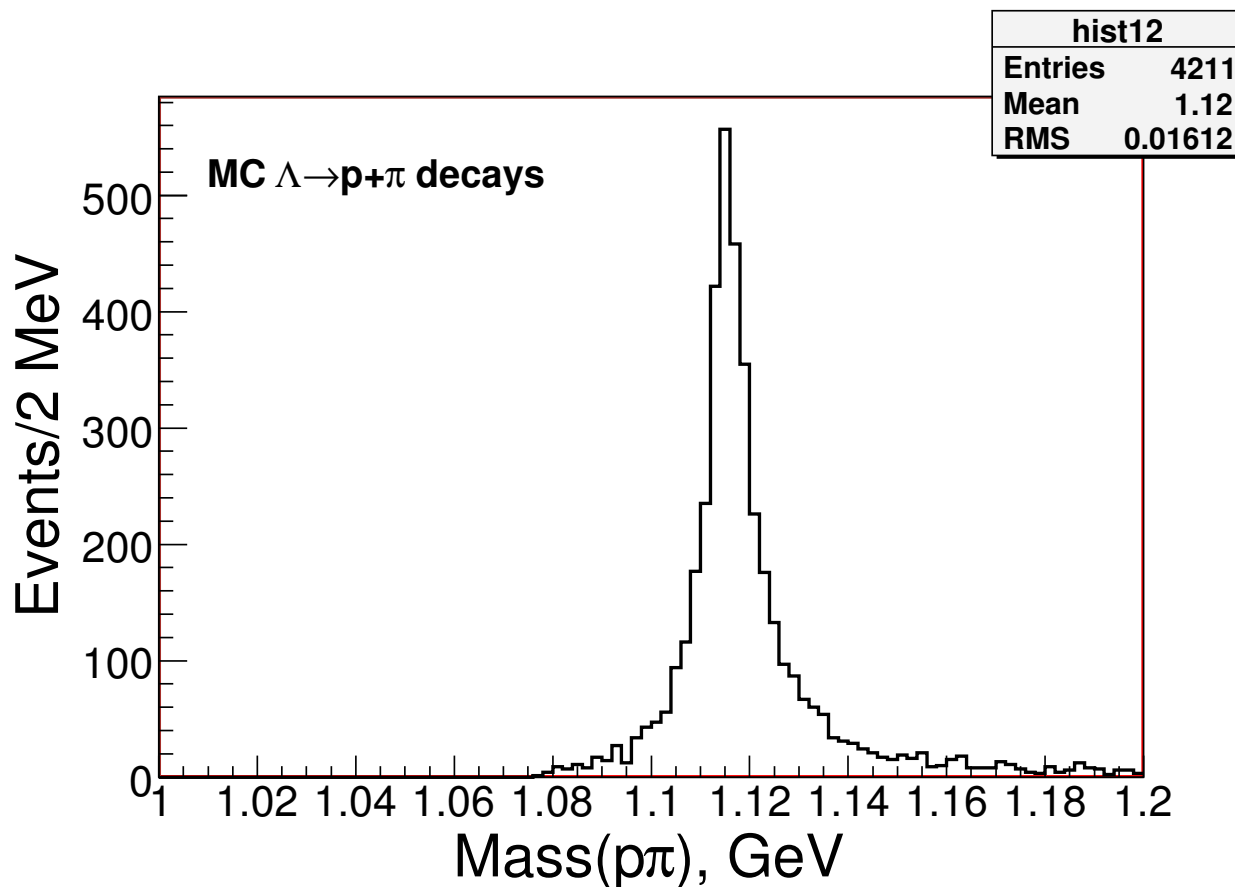


**Top** - the invariant mass distributions of pair positively charged tracks from the two track vertices.

**Middle** - deposited energy into HCAL with additional selection cuts: a) the mass of  $p\pi$  system should be within 1.1 - 1.4 GeV region and b) no any charged tracks pointing to the calorimeter area.

**Bottom** - the vertex Z position distributions of the multi-track vertices.

## cross-check



As a cross-check the analysis codes have been tested by reconstructing the Monte Carlo  $\Lambda \rightarrow p\pi$  decays. MC generation made by Durga. The number of generated  $\Lambda$ 's: 20K. Reminder:  $\Lambda$ 's branching fraction with charged decay modes is 0.62, neutrals - 0.36. The fraction of the single charged tracks found: 0.24. The fraction of the two track events is 0.22. Other events - 0.01. The position and width of the peak suggests that MC TPC detector simulation and B field are in good shape.

# $\Delta^{++}$ yield at 20 GeV/c

	LH2 + Sci	Empty Cryo + Sci	Carbon + Sci	Sci
proton beam triggers	33713	6969	14243	6506
incident protons (scaled using prescale)	5120519	843249	1438543	496286
beam trigger candidates	9	3	6	4
scaled beam candidates	2187	363	606	304
interaction trigger candidates	155	11	128	17
scaled interaction candidates	510	33	128	17
total candidates	2697	396	734	321
$\Delta^{++}$ yield ( $\times 10^{-4}$ )	$5.27 \pm 0.41$	$4.70 \pm 1.26$	$5.10 \pm 0.44$	$6.47 \pm 1.41$

Table 1: Yield of the  $\Delta^{++}$  candidates with 20 GeV/c proton beam on LH2 and Carbon 2% targets.

# $\Delta^{++}$ yield at 58 GeV/c

	LH2 + Sci	Empty Cryo + Sci	Uranium + Sci	Sci
proton beam triggers	21537	6463	38613	19642
incident protons (scaled using prescale)	74549887	32308413	60854088	23541880
beam trigger candidates	0	1	0	0
scaled beam candidates	0	3201(?)	0	0
interaction trigger candidates	7	4	5	5
scaled interaction candidates	168	96	55	94
total candidates	168	3297	55	94
$\Delta^{++}$ yield ( $\times 10^{-4}$ )	$0.023 \pm 0.009$	unclear	$0.009 \pm 0.004$	$0.040 \pm 0.018$

Table 2: Yield of the  $\Delta^{++}$  candidates with 58 GeV/c proton beam on LH2 and Uranium targets.

## Summary for $pp \rightarrow np\pi^+$ studies

- the  $\Delta^{++}$  peak clearly visible with 20 GeV/c protons. Outgoing neutrons are off from the HCAL aperture. Overall statistics is poor for the publication purpose.
- data with 35 GeV/c beam can not be used due to of lack the trigger counter performance.
- best momentum for  $\Delta^{++}$  studies is a few GeV/c, but we do not have incident protons on this range.
- Expected cross section at 20 GeV/c is about 2 mb, at 60 GeV/c it is much less than 1 mb. That why we do not see the  $\Delta^{++}$  peak at 60 GeV/c.

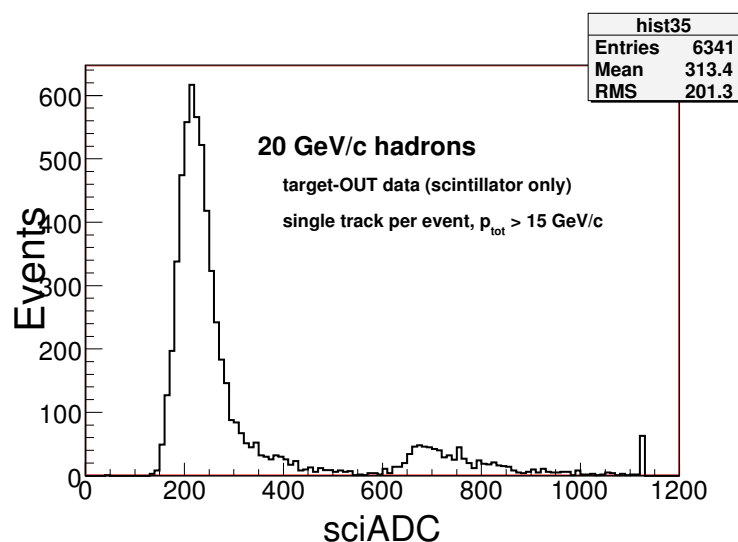
## The trigger counter studies.

### Motivation?

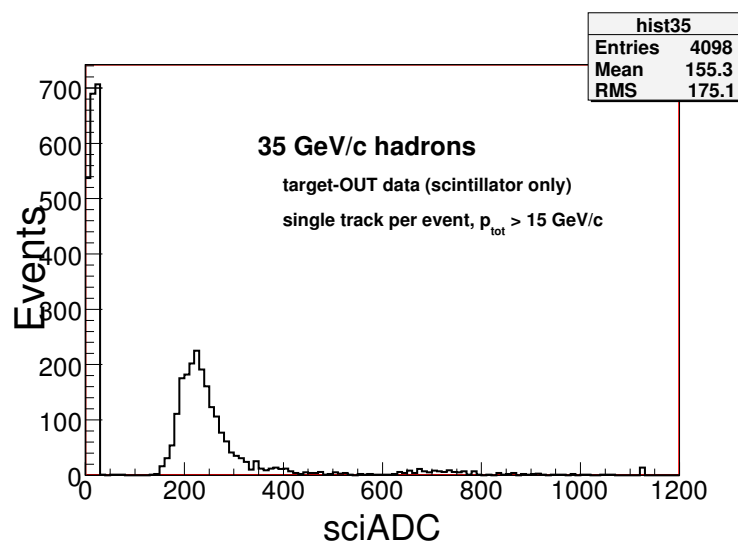
By using the trigger counter try to reduce the unreconstructed straight through tracks which is a major source of the background for the forward neutrons from the elastic  $p+n \rightarrow n+p$  reaction and for the inclusive neutron production.



# single track (vtx $\rightarrow$ ntrk == 1): what is a pulse height?

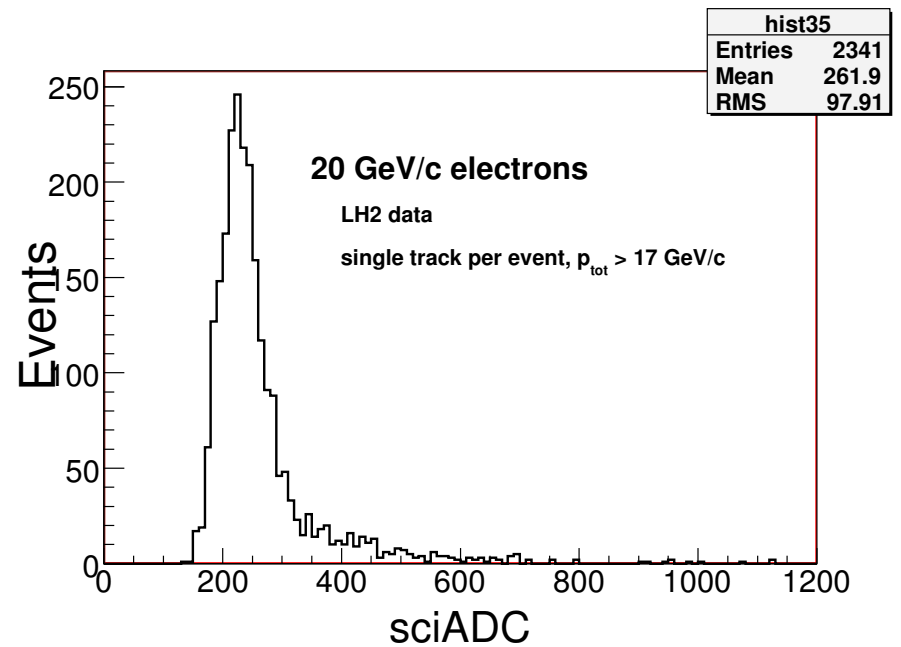
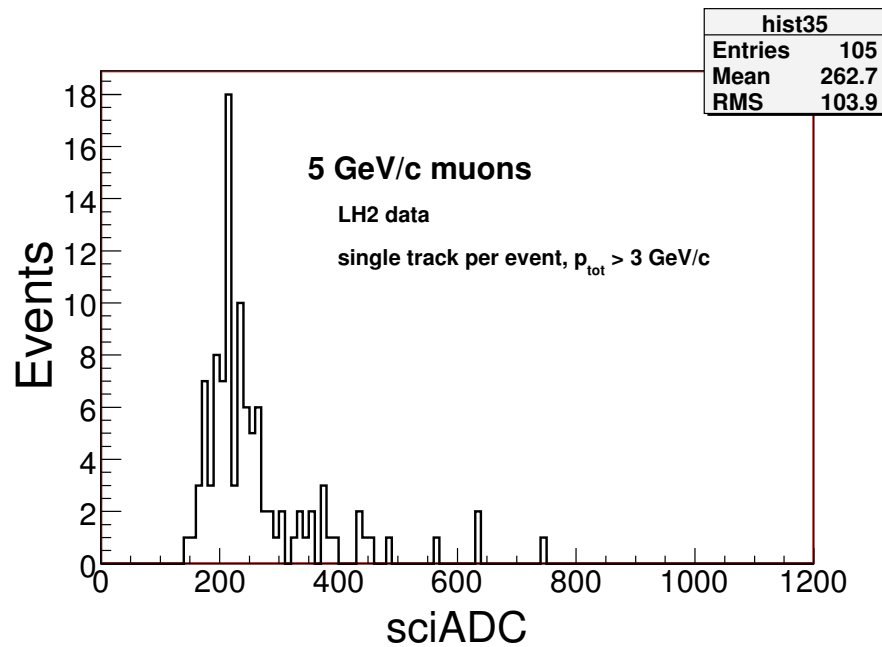


Top plot - the trigger counter's pulse height distribution on the 20 GeV/c hadrons. Bottom plot - the pulse height distribution on the 35 GeV/c hadrons.



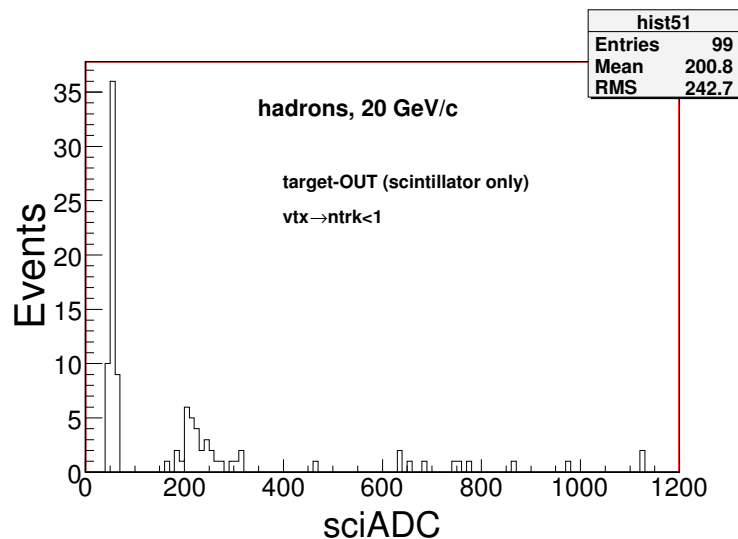
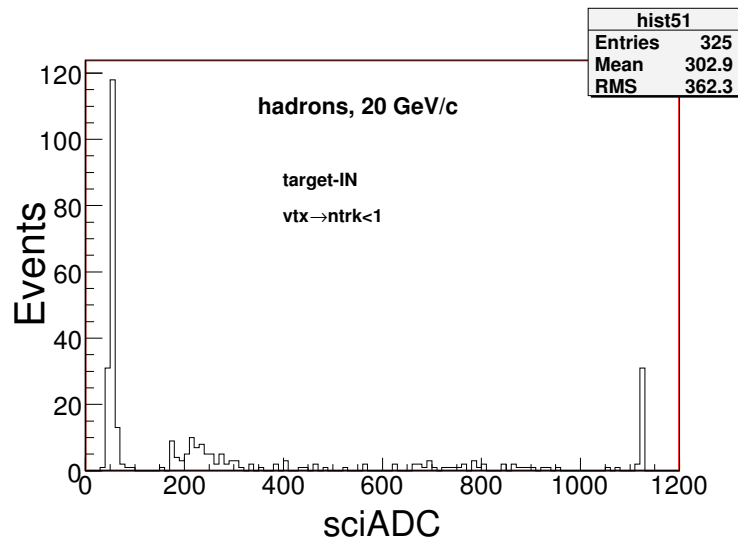
Events with  $\text{sciADC} < 35$  are mostly from runs  $< 12163$ .

## muons and electrons: what is a pulse height?



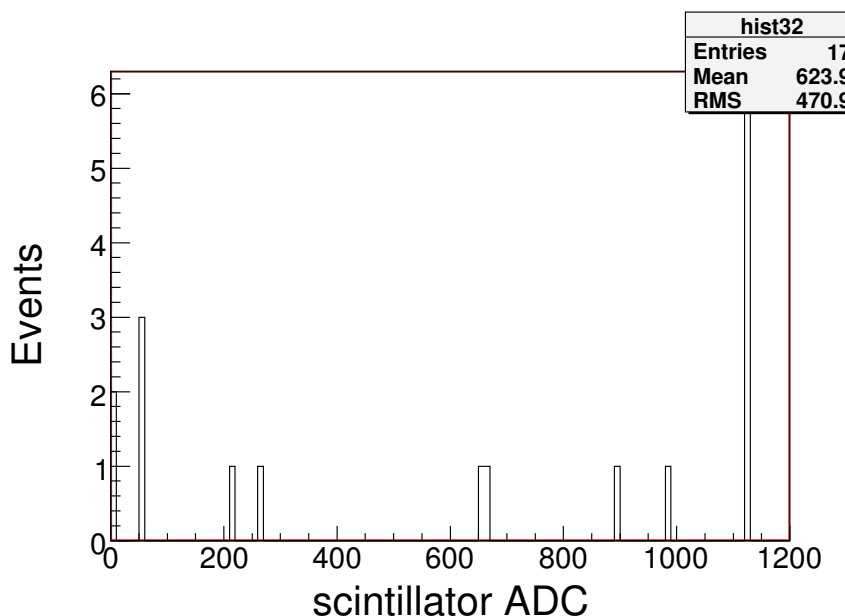
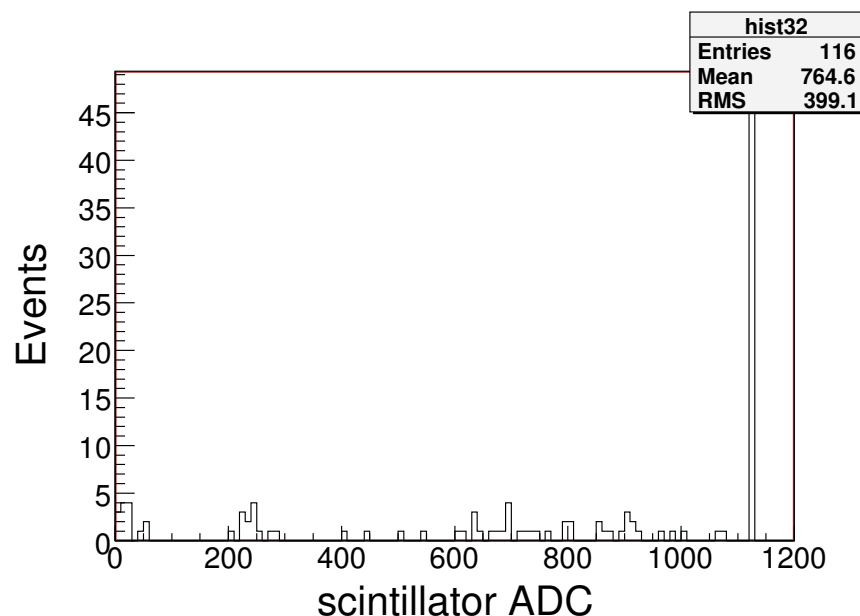
Left plot - the scintillator pulse height distribution on the 4.7 GeV/c muons. Right plot - using 20 GeV/c electrons.

## vtx $\rightarrow$ ntrk $< 1$ : what is a pulse height?



Data: 20 GeV/c and 35 GeV/c  $\pi^\pm$ ,  $K^\pm$  and protons (in order to have more statistics). nOutTrks: no any reconstructed tracks in TPC within  $\pm 3$  cm around the beam line (except if failed to reconstruct). Target-IN: Al, Be, Bi and C. Top plot - the scintillator pulse height distribution with Target-IN case. Bottom plot - Target-OUT data. Peak at 50 is a pedestal. Counts within 100 - 1100 range represents the unreconstructed straight through track events.

## soft tracks, $p_{tot} < 1$ GeV/c: what is a pulse height?



Data: 20 GeV/c and 35 GeV/c  $\pi^\pm$ ,  $K^\pm$  and protons (in order to have more statistics). Selection: look for the single soft track events with  $p_{tot} < 1$  GeV/c. Target-IN: Al, Be, Bi and C. Left plot - the scintillator pulse height distribution with Target-IN case.

Right plot - Target-OUT data.

Interpretation: data with  $\text{sciADC} < 100$  represents the  $n\text{OutTrks} = 0$  cases. Events within 150-1000 are the unreconstructed high momentum tracks due to of reco failures. But the scintillator seeing them. Overflow events ( $\text{sciADC} > 1100$ ) represents the pulse height for the single soft tracks.

## Summary for the trigger counter studies

- the pedestal is about 50 counts. On early runs ( $<12613$ ) ADC readings are below of the pedestal:  $\text{sciADC}=0$  or  $<35$  for the good single tracks going through. It is effecting mostly to 35 GeV/c data with the thin targets. Electronics failure?
- suggestion - do not use data if the readings are below pedestal
- pedestal - means there is no charged tracks within the counter acceptance
- the minimum ionizing peak is at 220 counts, the width - about 20 counts. The MIP position is consistent with a muon and an electron data.
- overflow - single soft track and/or multi-track cases